Power to Gas (& liquids)

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Publication date:
2013

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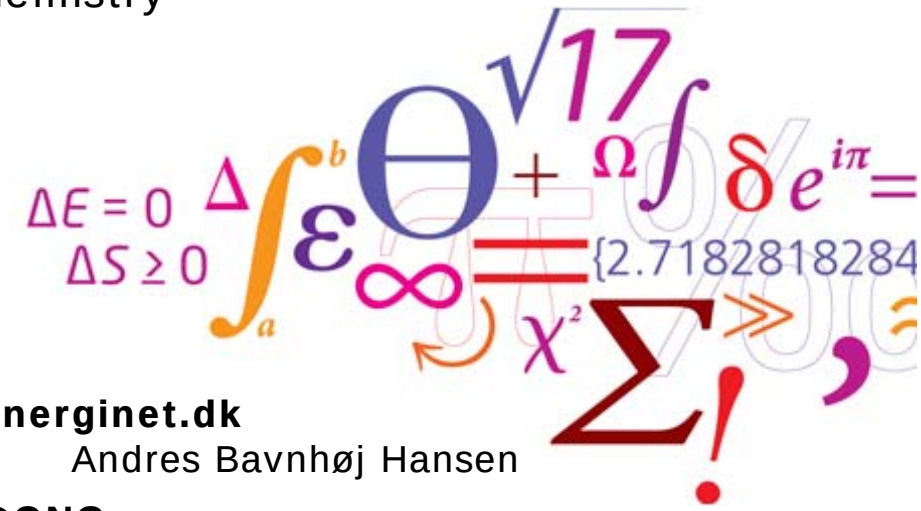

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Content

- Motivation: the wind power perspective
- State-of-art Power to gas
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- Ongoing developments
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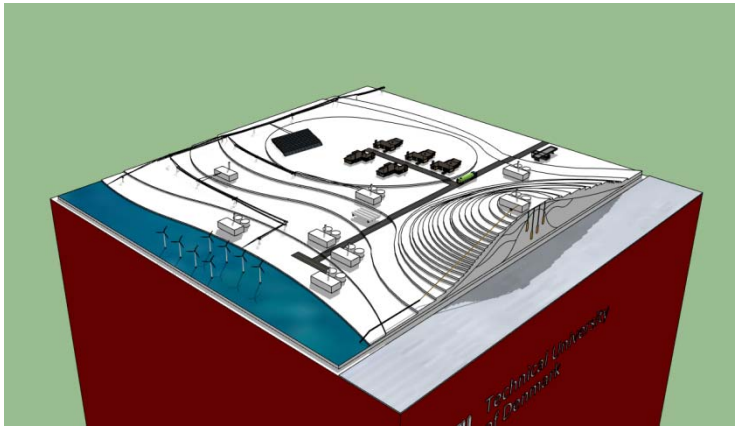
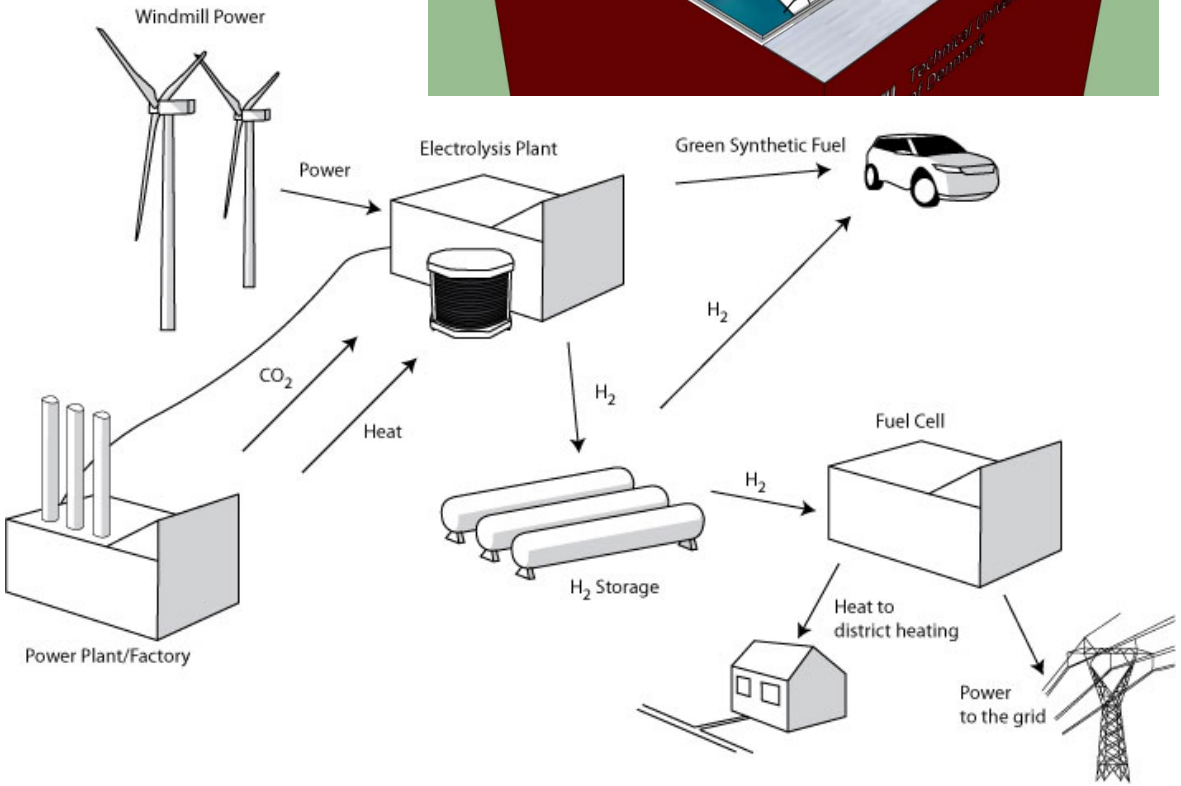
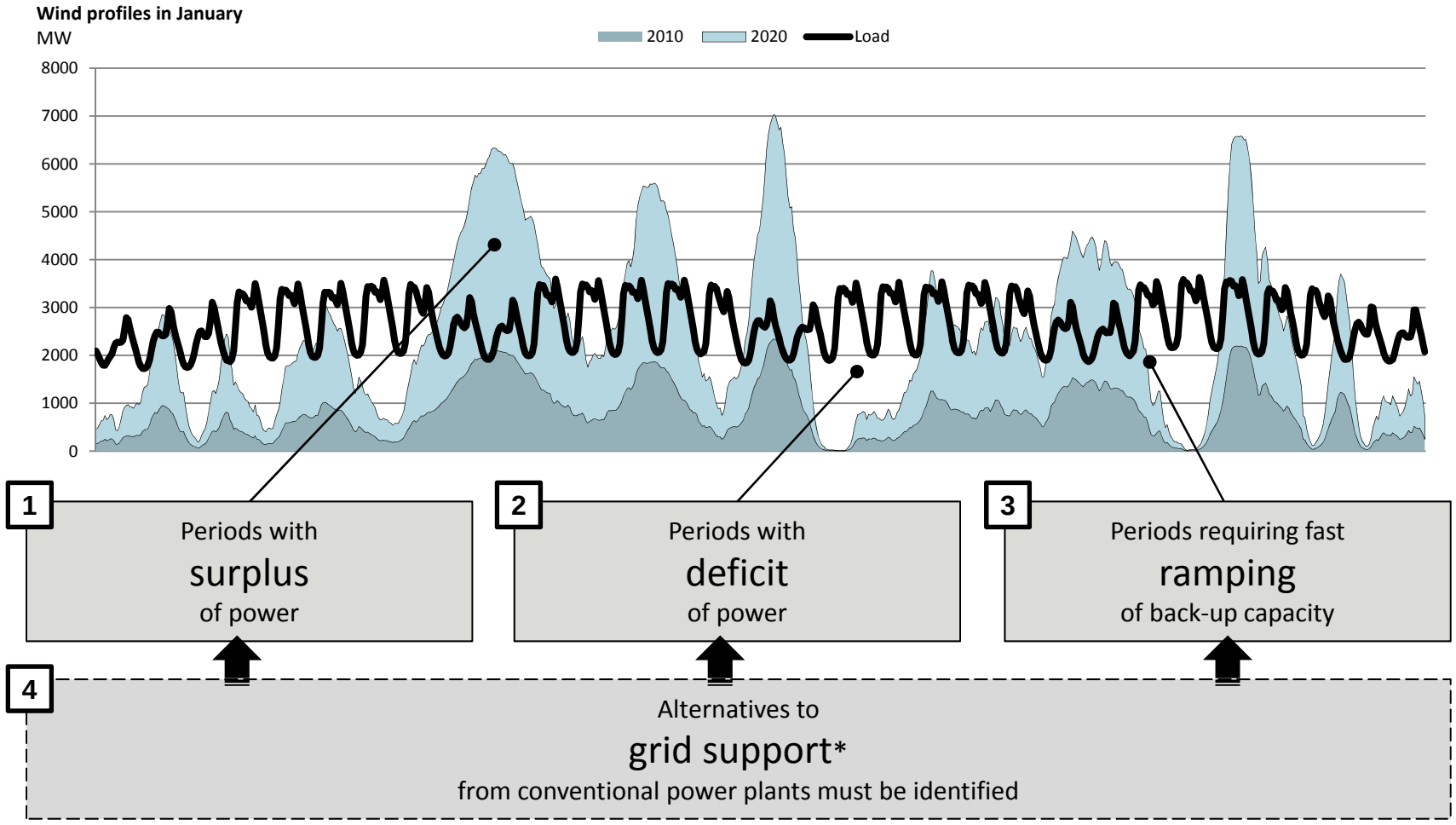




The intermittent nature of wind power challenges the existing electricity system



*Voltage and frequency control etc.

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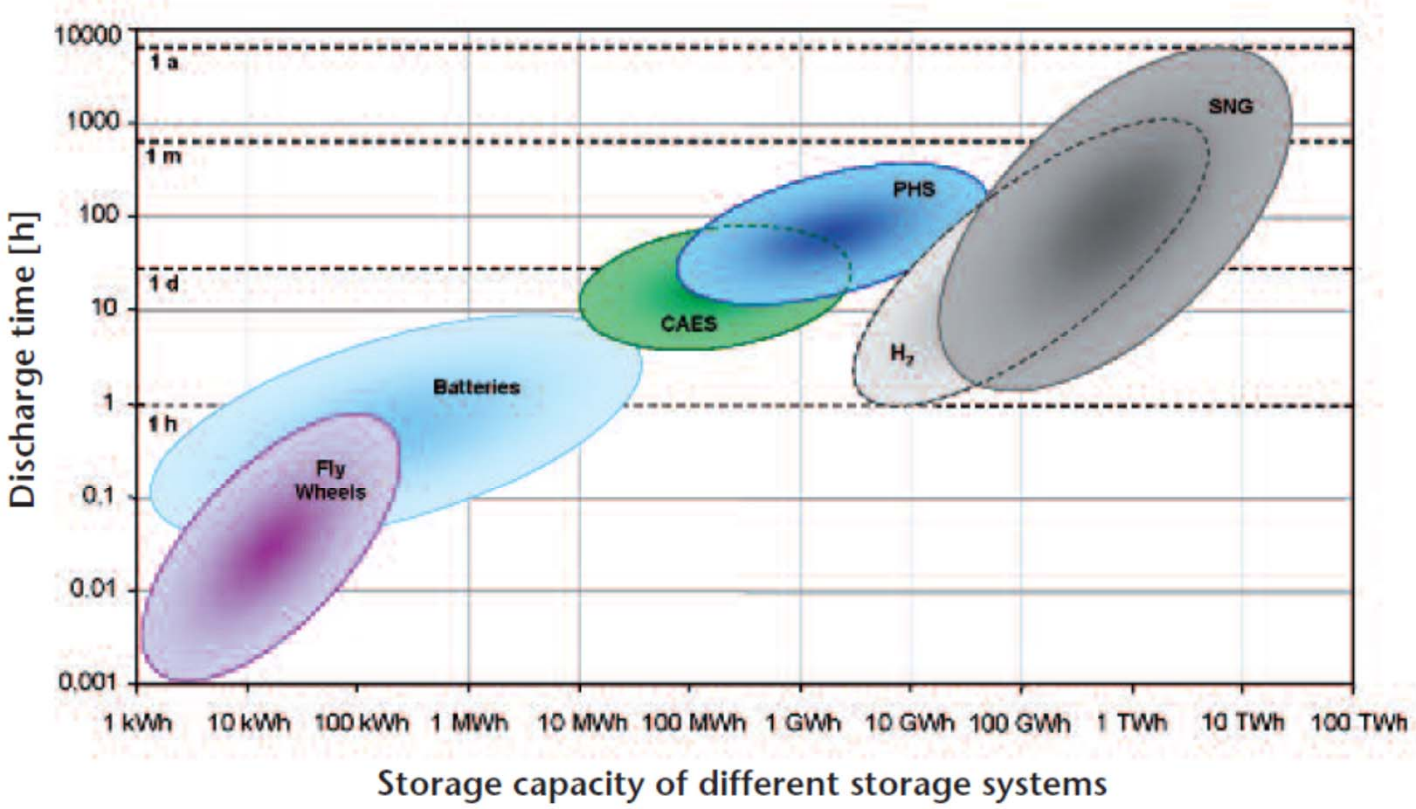
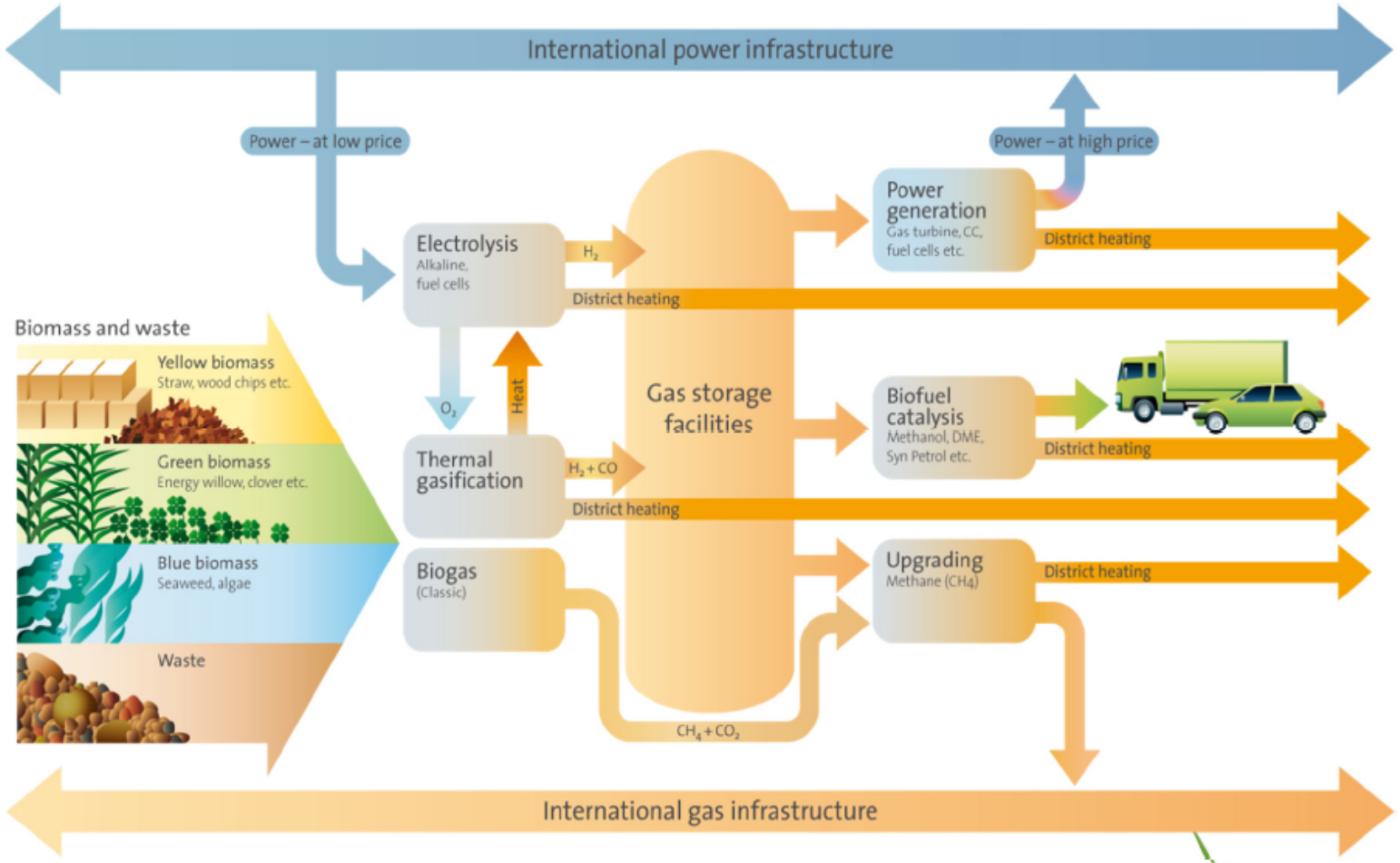
Electrical energy storage



CAES: Compressed Air Energy Storage (Druckluftspeicherkraftwerk)
PHS: Pumped Hydro Storage (Pumpspeicherwerk)
H_2, SNG: Die Untertage-Ausspeicherung beinhaltet die Rückverstromung in GuD-Kraftwerken (Gas- und Dampf)

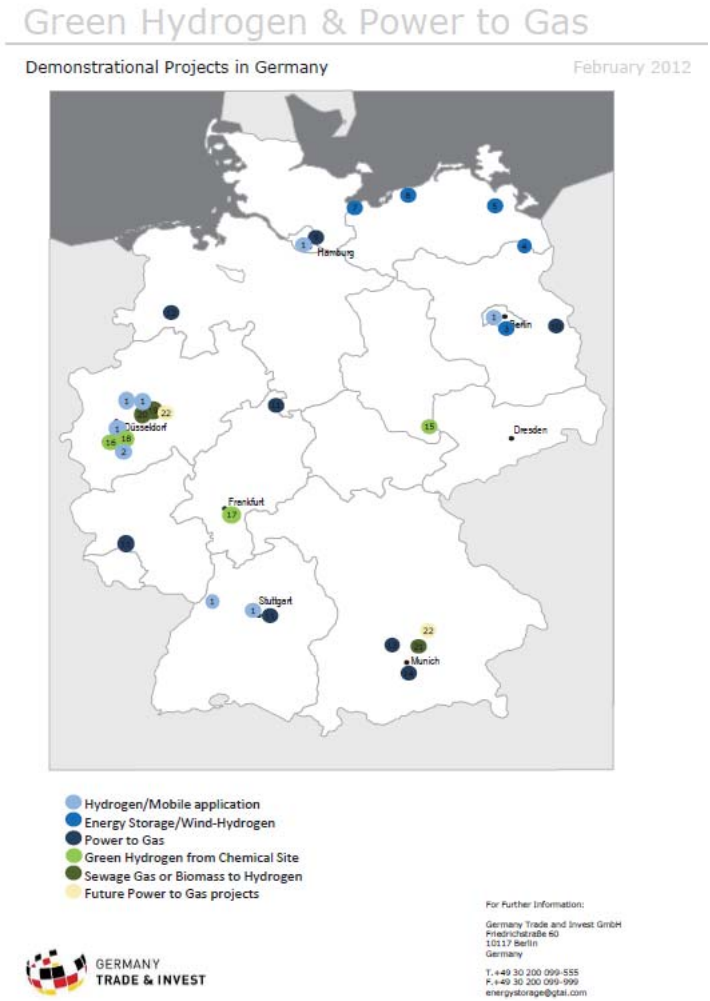
Specht et al. FVEE AEE Topics 2009

Integration of electricity, gas, fuel and heat systems

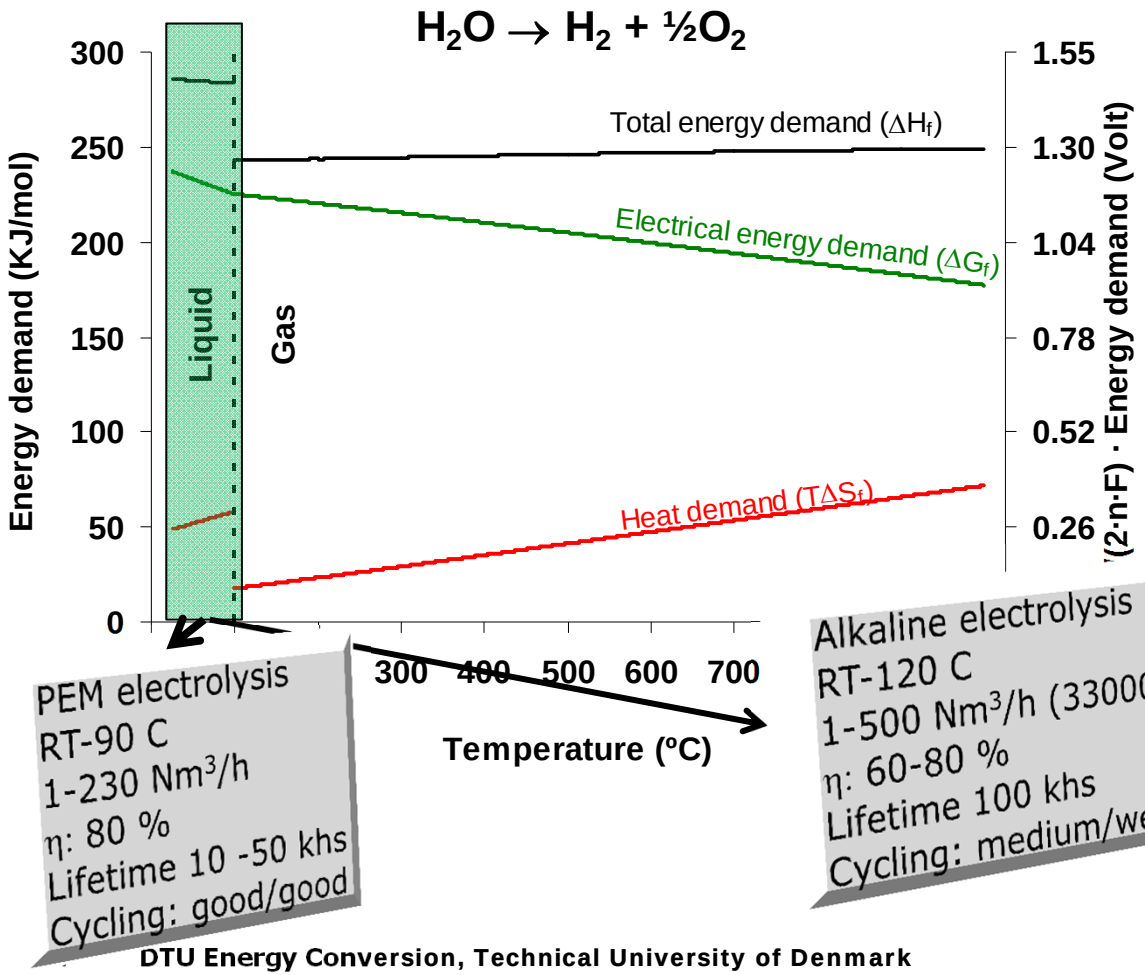


Power-to-Gas Demonstration around DK

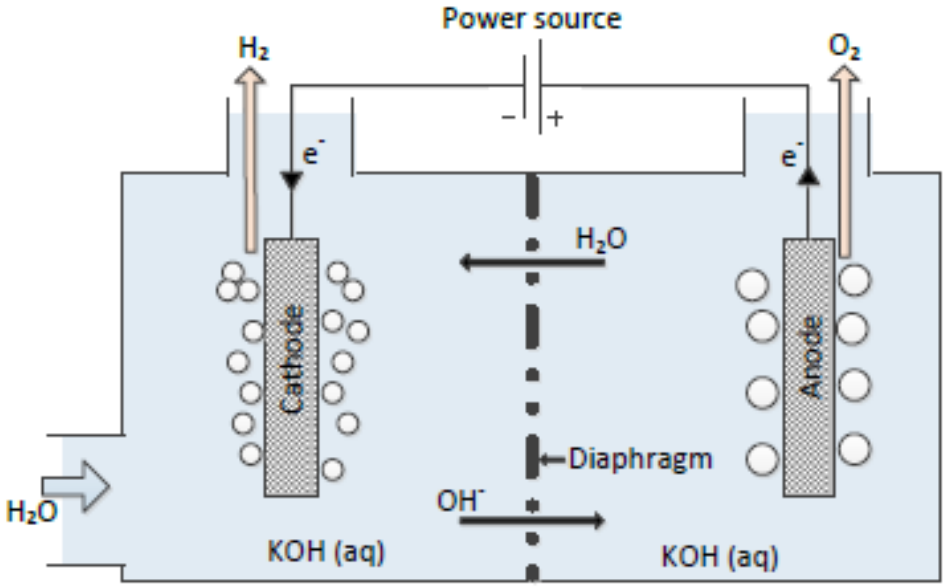
- Germany: already in the commercials in TV
  - Hydrogen
    - Falkenhagen (2MW)
    - Audi (Werlte) (later stage)
    - Eon Hamburg
    - Thüga Munich
    - Prenzlau (120 m^3/h
    - Werder (1MW)
  - Methane
    - Fraunhofer Stuttgart (25-250 kW)
    - Audi, Werlte (6,3 MW)
    - Graben Erdgas Schwaben (in planin
- Netherlands
  - NaturalHy: H_2 feed

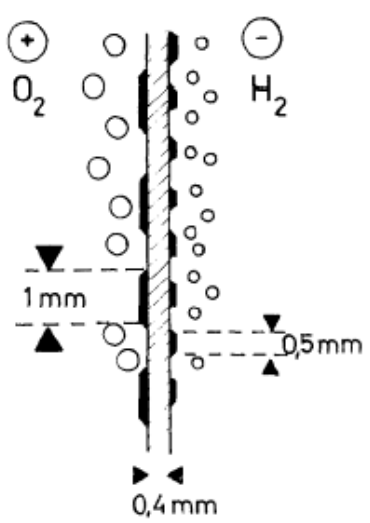


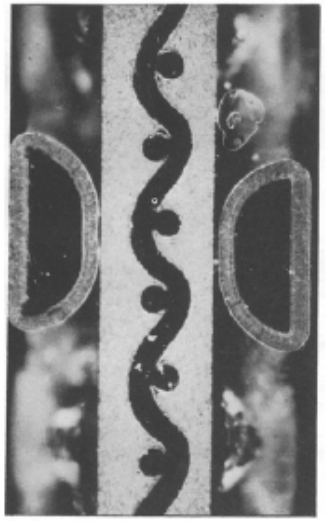
Power to Gas: H_2



Low temperature electrolysis cells



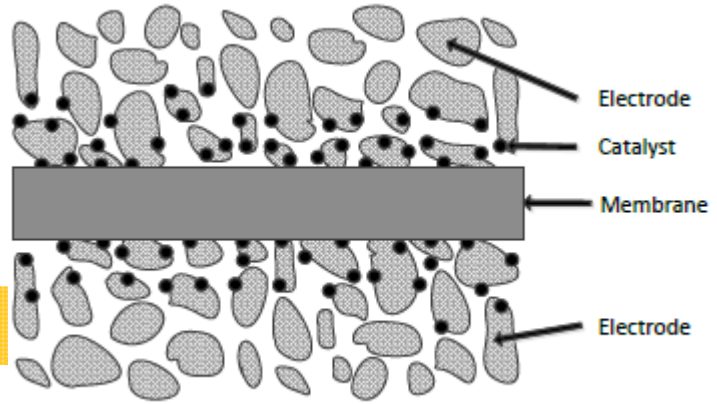




Separator
Diaphragma

Electro-catalysts

Electro-catalysts



Water electrolysis

AEC	Stat		
Current density	0.2 –		
Operating pressure	1-20		
Cyclability	poo		
Production capacity	50(		n
Non energy costs (Euro/Kg	5		

PEMFC			
Current density			
Operating pressure			
Efficiency non PGM catalysts			
Durability	10 000		000 hs
Non energy costs (Euro/Kg	5	2	

R&D for established water electrolysis

- **Alkaline water electrolysis**
  - Diaphragma development

ReSelyzer

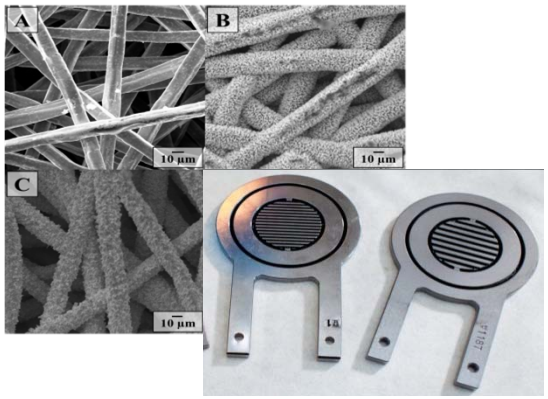
New Energy World JU
fuel cells & hydrogen for sustainability

  - Electro catalyst development
    - Conv. current density 0.2 – 0.5 A cm^2

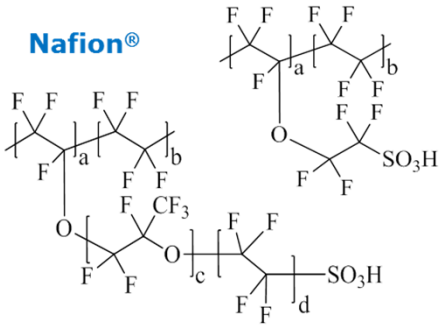
Alkaline Electrolysis

The Danish National Advanced Technology Foundation

- **Proton exchange membrane water electrolysis**
  - Bipolar plates
    - Ta coated steel



  - Membrane development

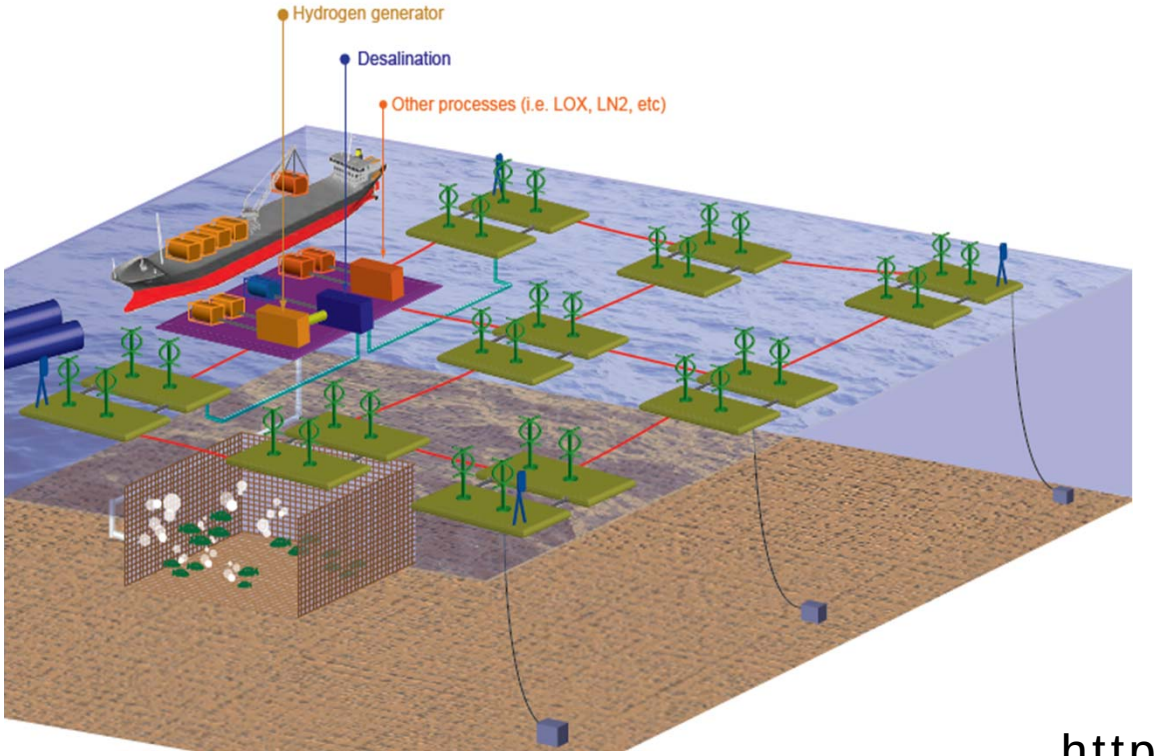


Aquivion™
"Short side chain"-PFSA

H2Ocean

Development of a wind-wave ocean platform equipped for hydrogen generation

2012-2014



Evaluation of electrolysis technologies suitable for this application

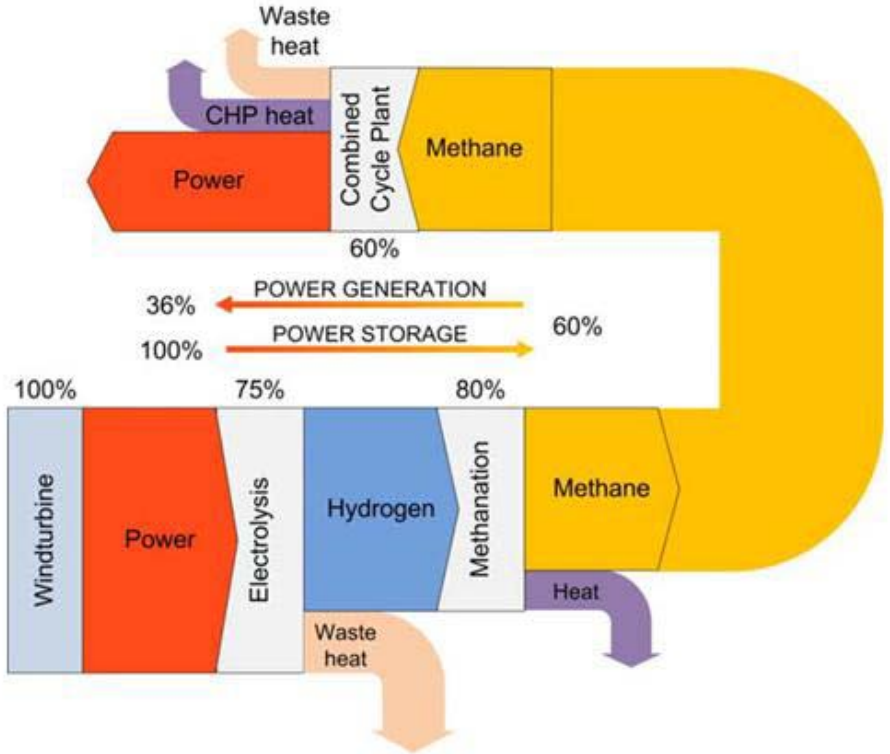
Sea water, desalination, electrolysis

Examine the **water quality** influence on the
- Degradation
- Lifetime
- Performance

http://www.h2ocean-project.eu/

Power to Gas: Methane

$$CO_2 + 4\,H_2 \rightarrow CH_4 + 2\,H_2O \qquad \Delta H^0 = -165{,}0\,\mathrm{kJ/mol}$$



60-65% SNG

35-40% Power

50-60% CHP

Vs. 0% due to power cut off / power curtailment

Source: Sterner 2009

Nr. 50

Conclusion (2) Economy for Power2Gas

- For Power2Gas the most dominat parameters are:
  Investment cost (Capex) and power price.

- No economic balance with present level for technology, cost and power prices

- With Energistyrelsens expectations for the development in power prices (5,3 c/kWh in 2030) and 75% system efficieny, 8000 operating hours/year - the Capex for "green methane" must drop to a level –

  - **below 1000 €/kW**

  before economic balance. (Report from DOE indicate achievable Capex for SOEC at a level of 300 – 400 €/kW)

- For a hydrogen production from 2030 (80% efficiency and 8000 hours of operation/year) the similar indicated level is

  - **below 1300 €/kW –**

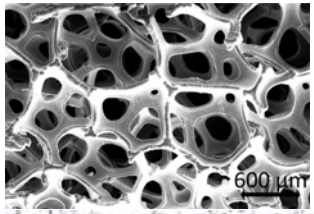
but in any case:

a future for Power2gas – is totally depending of further development of the technologies in question

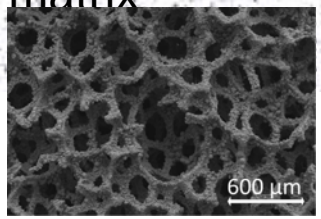
DONG

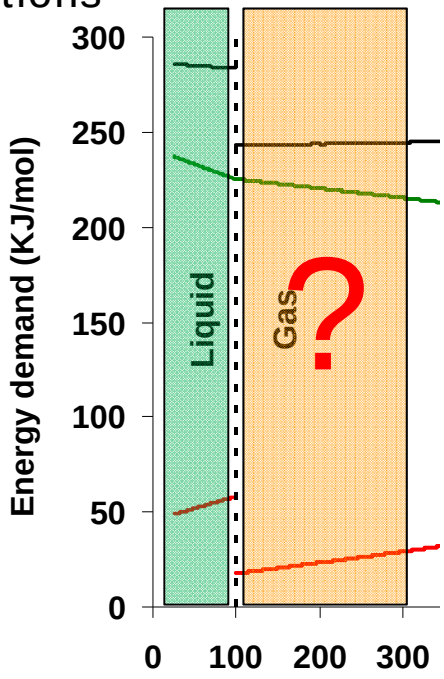
Advanced ”Low T” electrolysis concepts

- Immobilised liquid electrolytes
  - Alkaline solutions



porous ceramic matrix





- solid electrolytes
  - Anion exchange membranes
  - phosphate materials with proton conductivity between 200 – 400 C

Medlys

Danish Agency for Science Technology and Innovation
Ministry of Science, Innovation and Higher Education

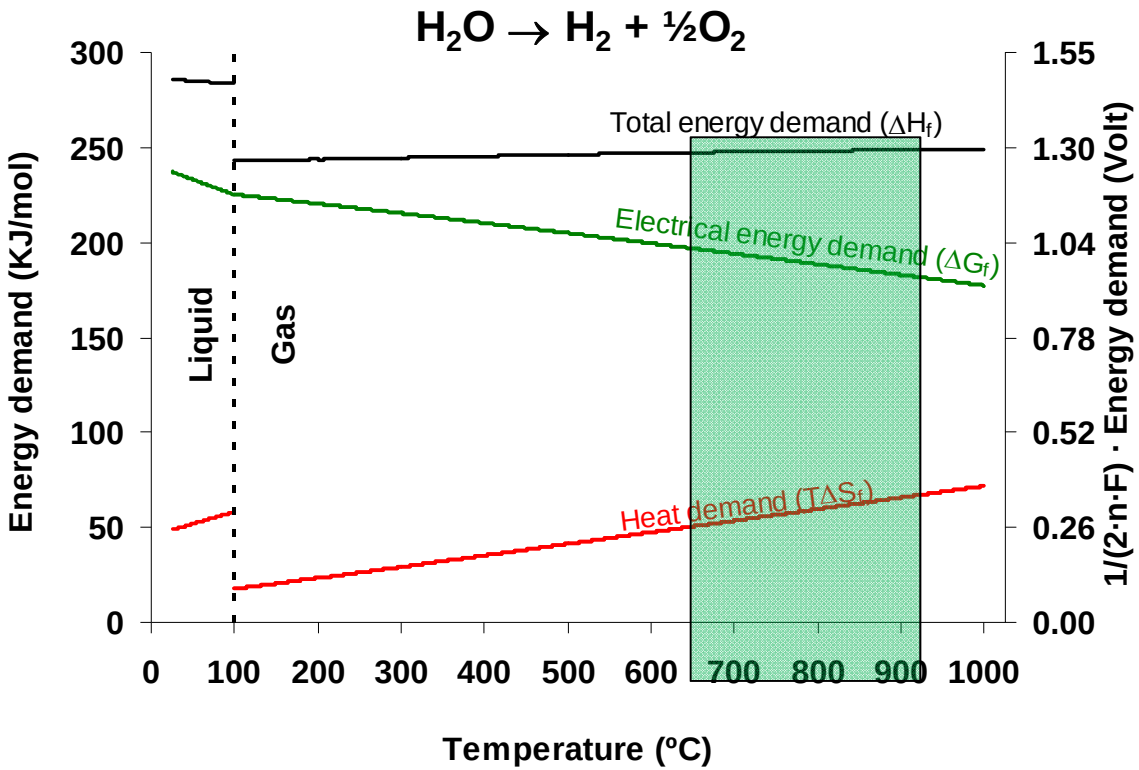
pro-con Danish-Chinese Centre for Intermediate Temperature Proton Conducting Systems

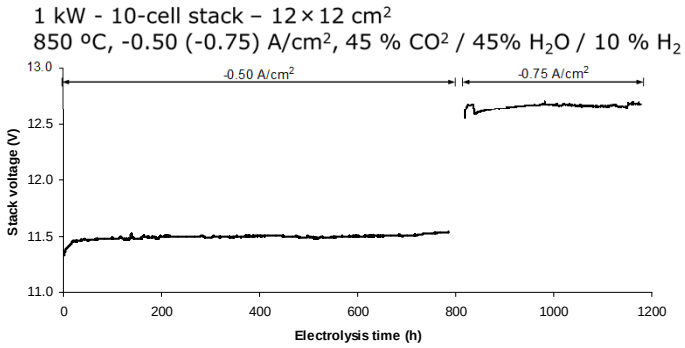
Danmarks Grundforskningsfond
Danish National Research Foundation

eUDP

CASE
Catalysis for Sustainable Energy

Solid oxide electrolysis technology





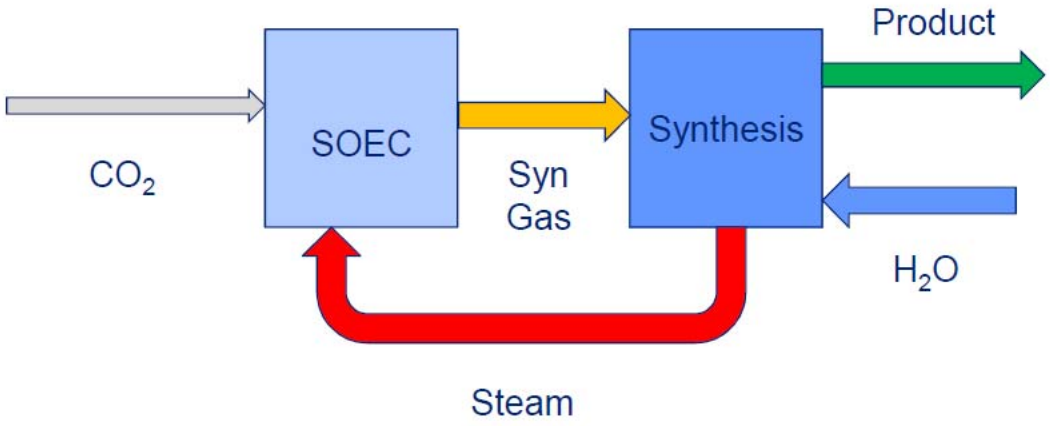
Co-electrolysis: $H_2O + CO_2 \rightarrow$ **H_2 + CO** + O_2

See als pres. from Søren Højgaard Jensen:
Session Fuel Cells and H2 Technologies

Solid oxide electrolysis
600-900 C
η: ?? %
Lifetime ??
Cycling: ??

Power to Gas: system integration aspects

Synergy between SOEC and fuel synthesis



HALDOR TOPSOE

Power to gas / liquid fuels: thermal integration

Heat of Reactions per mole H_2 @ 280 °C

Product	From CO kJ/mol	From CO_2 kJ/mol
Gasoline	79	37
CH_4	72	44
DME	55	24
MeOH	50	20

Evaporation of 1 mol of water requires ~48 kJ @ 25 – 60 bar g

NB: Steam conversion is only 70 – 80 % in SOEC plants

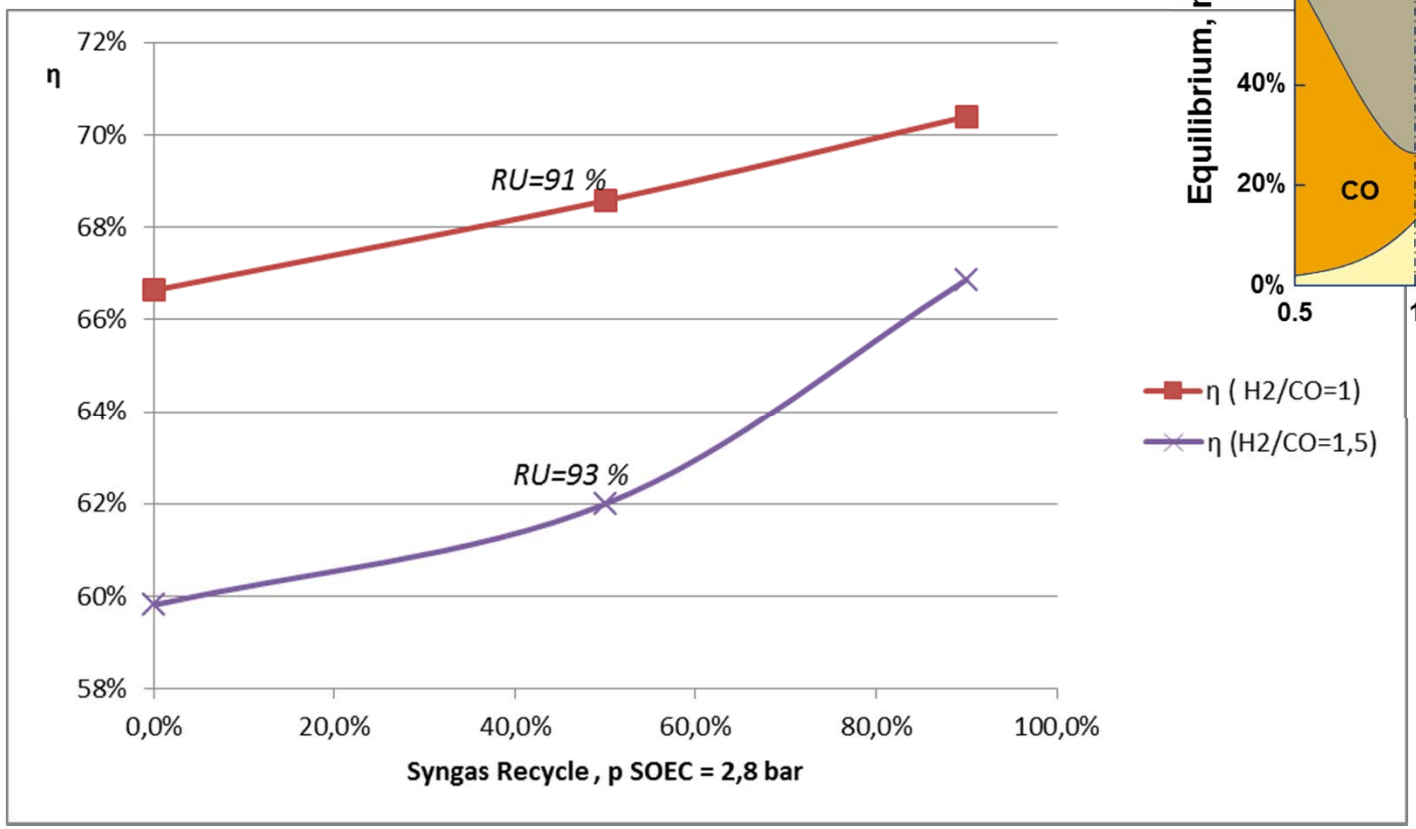
HALDOR TOPSOE

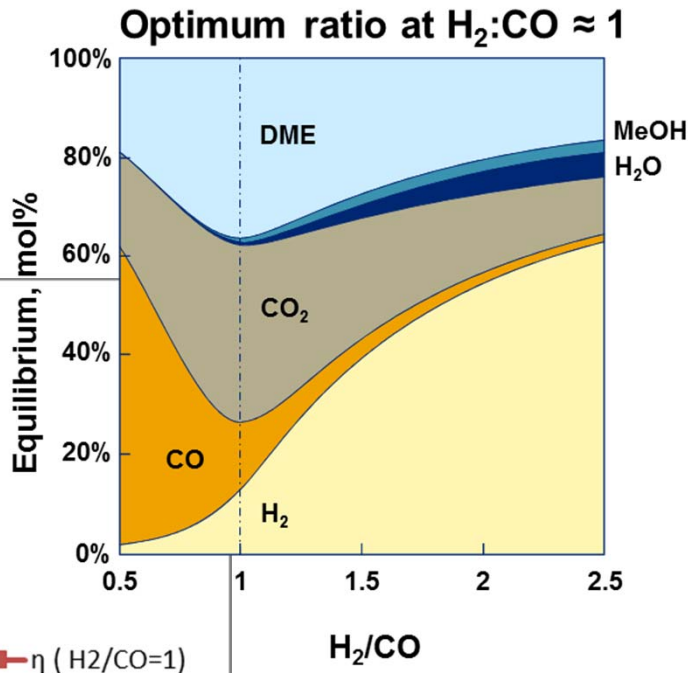
DME /MeOH: matches syn gas (SOEC product output)

CH_4: matches Biogas upgrading

SOEC-DME simulation - Low pressure case

Two step process: Syn gas → MeOH → DME
Plant efficiency for different values of investigated parameters, low p SOEC configurations

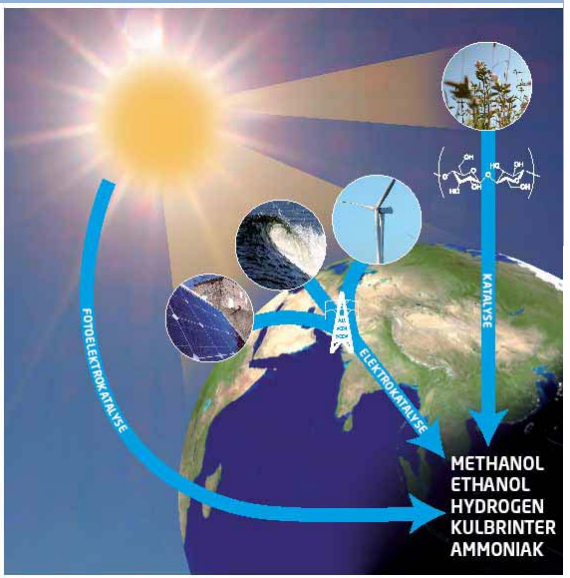


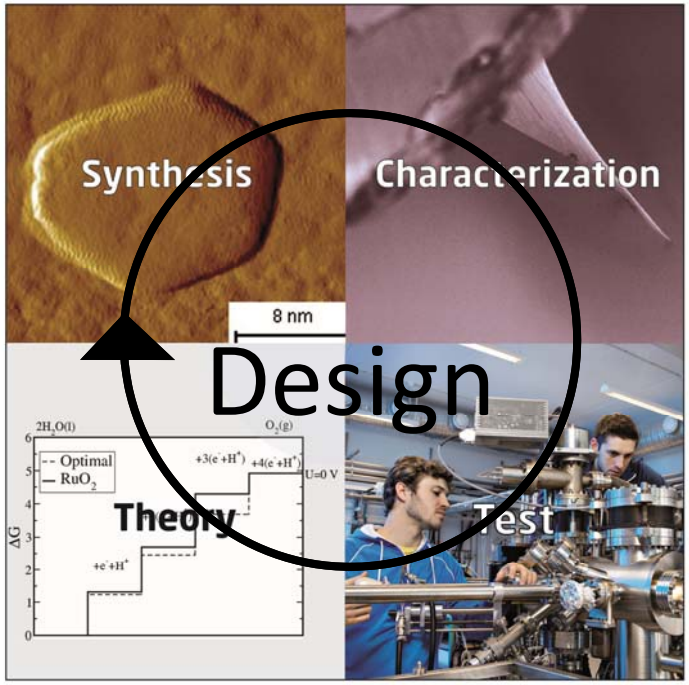


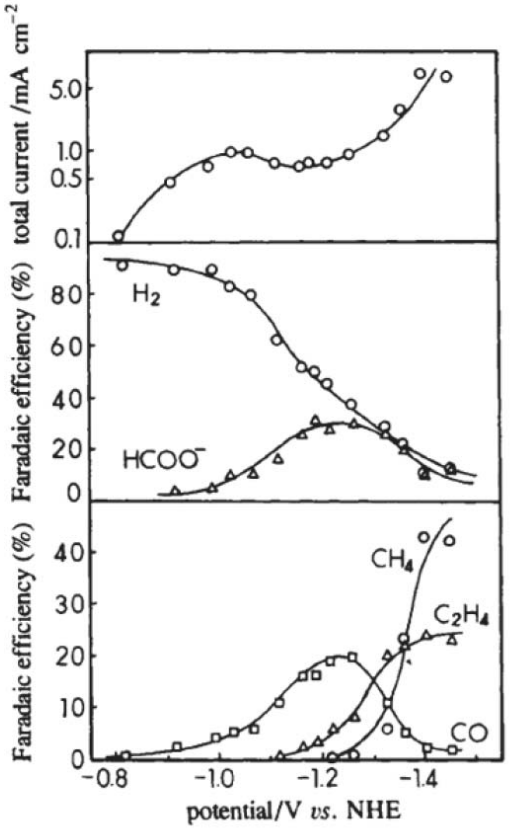
CASE

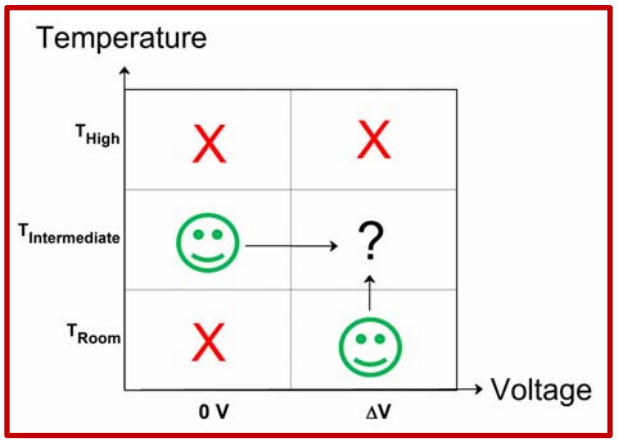
Catalysis for Sustainable Energy

The ”Dream”









Fixation of CO_2 and N_2
into
synthetic fuels
(MeOH, NH_3)

Cu electro catalysts

RT, liquid electrolytes

IT, new electrolytes

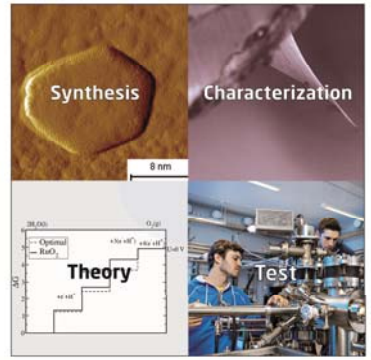
Y. Hori, A. Murata, R. Takahashi, *Journal of the Chemical Society, Faraday Transactions 1: Physical Chemistry in Condensed Phases*, 85 (1989) 2309-2326.

Power To Gas & Liquids: A personal outlook

- Gas others than H_2 requires considerations of (at least) two reactions
- This could be in principle:
  - Serial processes
  - Integrated processes

- Direct electrochemical fuel synthesis

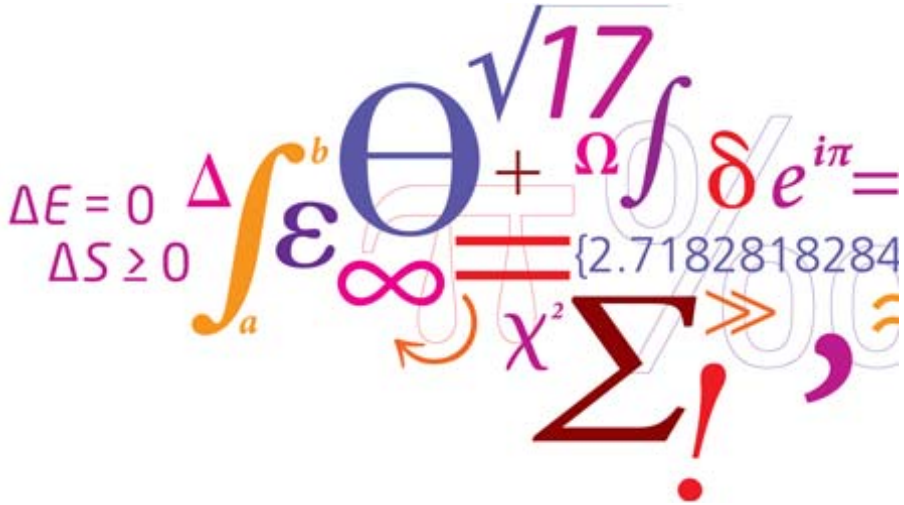
- Advanced H_2O electrolysis + methanation
- co-electrolysis & Fischer Tropsch
- Eff > 60% CH4, 50-60% rd. Trip ?



- Coventional H_2O electrolysis
- Methanation
- eff 60% CH4 / 35 % rd. trip

now midterm longterm

Thank you for your attention



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